Health and Fisheries of the Major River Ecosystems of India

With Emphasis on River Ganga

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Organized by

Central Inland Fisheries Research Institute, India
Aquatic Ecosystem Health & Management Society, Canada

Co-chairs

A.P. Sharma, India

M. Munawar, Canada

AQUATIC ECOSYSTEM
HEALTH & MANAGEMENT SOCIETY

Preface

India is endowed with rich water resources. Approximately 45,000 km of long riverine systems are intertwined across the length and breadth of the country. These include the Himalayan snow fed and peninsular rain fed rivers. There are 14 major rivers in India of which 4 are perennial. Ganga, Brahmaputra, Brahmani, Cauvery, Godavari, Indus, Krishna, Mahanadi, Mahi, Narmada, Periyar, Sabarmati, Subarnarekha and Tapti cover 83% of the drainage basin and account for 85% of the surface flow. Among them, the river Ganga occupies a unique position in the history, culture, religion and civilization of the Indian subcontinent. The drainage basin of the Ganges covers one of the most populated regions of the world where the Indo-Aryan civilization has flourished for many centuries and forms the life line of India. These major rivers of India harbour extremely rich biodiversity and contribute significantly to the food security and livelihood of India.

In recent decades, India's water resources and especially her rivers have been exposed to various anthropogenic stresses. Human greed and abuse has degraded these ecosystems significantly. Human impacts include the construction of numerous multipurpose reservoirs for irrigation, water supply, and hydro-power as well as many barrages for water diversion. Several long reaches of rivers passing through urban areas remain completely dry for large parts of the year, except during monsoon because of these uses. These flood plains are lost and even river beds are cultivated during dry periods. As a result of such habitat degradation fish catches have greatly declined, the size of important indigenous fish species decreased and fish recruitment has been seriously affected.

It is indeed a matter of extreme concern that out of the world's 30 river basins identified as global level priorities for maintenance and protection of aquatic biodiversity, 9 of these are Indian namely Brahmaputra, Cauvery, Ganges, Godavari, Indus, Krishna, Mahanadi, Narmada, Pennar and Tapi. This situation has developed due to the inability of most resource managers to adopt a comprehensive and holistic approach to balance the demands of ecosystem health against the equally compelling needs of other stake holders. Consequently, in order evaluate the deteriorating situation, a special symposium entitled Indian River System was organized jointly by CIFRI and the AEHMS (Aquatic Ecosystem Health & Management Society, Canada) during the 8th Indian Fisheries forum held in Kolkata, 2008. It was felt that the major river systems in India must be viewed holistically with integrated watershed perspectives in mind.

The data available on the fishes, fisheries and the health of these rivers in India are fragmented and scattered. To remedy this glaring lacuna, the CIFRI - a premier research organization of India - has generated a valuable data base dealing with the ecology, biodiversity, fisheries, aquatic health, management and conservation of the major Indian rivers over the past several years. During the Fisheries Forum symposium of 2008, it was suggested that a concerted effort be made to collect, compile and integrate the available literature and data on the major rivers of India which will lead to a realistic and scientific assessment of the current status of the health of these rivers. In order to fill in the

information gap in the primary literature, the AEHMS published a special issue of Aquatic Ecosystem Health & Management (AEHMS, 2010) in 2010 that includes a compendium of peer reviewed papers focusing on the ecosystem health of river Ganges. The joint collaboration continued between CIFRI and AEHMS. To maintain the momentum, plans for two further publications were drawn up following an organizational meeting held in New Delhi during February 2011, namely:

1. Ecosystem Health and Management of River Ganga
2. Health and fisheries of the major river ecosystems of India

In order to proceed with these publications, an "authors' workshop" entitled 'Ecosystem Health of Major Rivers of India: River Ganges Case Study' was organized jointly by CIFRI and the AEHMS in Barrackpore during April 2012 where several scientists presented their research findings. As a result of this workshop and a follow up meeting in July 2012, several papers were submitted to the AEHMS for peer reviewed publication. At this juncture, it was felt that it would be useful and productive to organize a special all India symposium to provide a broad platform for scientists to expose their research findings pertaining to history, ecology, biodiversity, geomorphology, hydraulics, conservation and management of river Ganga as well as other major rivers of India.

With this background work behind us, the CIFRI, AEHMS & IFSI (Inland Fisheries Society of India) are pleased to jointly sponsor this International Symposium entitled "Health and Fisheries of Major River Ecosystems of India with emphasis on River Ganges" in conjunction with a great event: the 100th Indian Science Congress at Kolkata. The response to the symposium has been overwhelming with 38 papers expected during the two days of deliberations providing a excellent opportunity of a top down assessment of the status of the ecosystem health of Indian rivers. The symposium will also provide a valuable opportunity of interactions amongst scientists for exchange of ideas and collaboration. We welcome all the participants and wish them an interesting and productive experience. We would like to thank all participants and the staff including Jennifer Lorimer, Lisa Elder, Susan Blunt (AEHMS); Mark Fitzpatrick (Fisheries & Oceans Canada) and Sajina Ali (CIFRI) for their assistance in various aspects of the development of the project. We are grateful to Drs. C.K. Minns (Scientist Emeritus, Fisheries & Oceans Canada) and N. Mandrak (Fisheries & Oceans Canada) for the continuing support and advice towards the development of this landmark project.

Co-conveners

Dr. Anil Sharma, Director CIFRI
Barrackpore, India

Dr. M. Munawar, President & Chief Editor
AEHMS, Canada

Aquatic Ecosystem Health and Management Society, 2010. Special issue: Ecosystem Health of the Majestic River Ganges. AEHM 13, 4.

“Ganga has been a symbol of India’s age-old culture and civilization, ever-changing, everflowing, yet the same Ganga”

Pandit Jawaharlal Nehru
Prime Minister of India
From his will and testament

Welcome to the AEHMS

The Aquatic Ecosystem Health & Management Society (AEHMS) was established in 1989 to encourage and promote integrated, eco-systemic and holistic initiatives for the protection and conservation of aquatic resources of the world. The Society has four broad objectives centering on health, management, the convening/sponsoring of conferences/symposia, and publications via its international primary journal, monograph series and its website (www.aehms.org). The objectives of the Society are outlined below:

- Adoption and promotion of ecosystem health concept.
- Application of integrated management from a multi-disciplinary, multi-trophic and sustainable perspective.
- Focusing on integrated approaches for protection, remediation, and restoration.
- Enhancing understanding of marine and freshwater ecosystems: structure, function, ecology, biodiversity, etc.
- Advocating the development of new approaches, tools, techniques and models.
- Encouraging interdisciplinary communication amongst scientists, managers, universities, governments, industry, and public sector.
- Organizing and co-sponsoring international conferences, symposia, workshops, eco-forums and working groups.
- Publication of an international primary journal, special issues and peer reviewed book series.

The Society is actively involved in primary and peer-reviewed publications. It publishes an international journal, ***Aquatic Ecosystem Health and Management (AEHM)*** on a quarterly basis (in collaboration with the publisher Taylor and Francis, Philadelphia). From 2007 onwards the AEHM was selected by Thomson Scientific for coverage in the Science Citation Index Expanded (SciSearch®); Journal Citation Reports; Current Contents®/Agriculture, Biology, and Environmental Sciences; Zoological Record; Biological Abstracts; and BIOSIS Previews. It has published over **30** special issues on diverse topics from across the world. Currently, plans are under way for publications on: the ecology of Lake Superior; the state of the (Arabian/Persian) Gulf ecosystem; ecosystem health and recovery of the Bay of Quinte; managing ecosystem health of tropical seas and coastal ecosystems; marine environmental changes in the South China Sea; and ecosystem health of River Ganges and other major rivers of India. A full list of the special issues is given at the back of this Program book.

In addition, the AEHMS also produces a peer reviewed book series under the banner of the ***Ecovison World Monograph Series***. It has already published over 20 peer reviewed books on a variety of subjects and aquatic environments (see the list given at the end of this Program book). One of its books, *Burning Rivers*, has just won the 2011 Green Book Festival Award in the scientific category.

Upcoming Society events include the following conferences and symposia:

- Health and Fisheries of Major River Ecosystems of India with Emphasis on Ganges. Kolkata, India, January 2013
- Aquatic Ecosystem Health: Linking Toxicology and Ecology. Burlington, ON, Canada, April 16-17, 2013
- AEHMS11 - Aquatic Ecosystems at the Edge: Managing for Sustainability. Victoria, BC, Canada, June 17-20, 2013
- Marine Invasive Species: Management of Ballast Water and Other Vectors. Muscat, Oman, 2014

The Society welcomes individuals for membership belonging to a wide range of disciplines. AEHMS cordially invites you to join the Society to support global conservation and education. Membership includes 4 quarterly issues of the journal with on-line access, as well as discounts on conference registration fees, purchases of Ecovision books and back issues of our journal. A discounted membership is available for the participants of this conference, students and retired colleagues

M. Munawar
President:
Aquatic Ecosystem Health & Management Society

AQUATIC ECOSYSTEM
HEALTH & MANAGEMENT

ECOVISION
World Monograph Series

Program

Saturday, January 5th			
	Inaugural Session		
2:00-2:10	A.P. Sharma		Inaugural Speech
2:10-2:20	S. Ayyappan		Plenary Address
2:20-2:45	M. Munawar		**Keynote:** Freshwater Fishes and Fisheries of the World: Health, Biodiversity and Management
Session 1.	**River Ganga**		
2:45-3:00	S1.01	Kumar, D.	River Ganga - historical, cultural and socio-economic attributes
3:00-3:15	S1.02	Jha, B.C.	Algal biodiversity in the lower stretch of River Ganges
3:15-3:30	S1.03	Kumar, R.	Patterns in zooplankton community structure and distribution along the Patna to Chak (Begusarai) stretch of the River Ganga in Bihar
3:30-3:45		**Tea break**	
3:45-4:00	S1.04	Nautiyal, P.	Ecosystem health indicators in the Ganga Basin (Uttarakhand, India): Biodiversity and spatial patterns in structure and distribution of benthic diatoms, macroinvertebrates and ichthyofauna
4:00-4:15	S1.05	Das, M.K.	Fish diversity, community structure and ecological integrity of the tropical river Ganges, India
4:15-4:30	S1.06	Chitranshi, V.R.	Vanishing fish habitats of River Ganga
4:30-4:45	S1.07	Singh, A.K.	Invasion and impacts of alien fish species in the Ganga River system, India
4:45-5:00	S1.08	Bhaumik, U.	Fisheries of Indian Shad (*Tenualosa ilisha*) in the Indo-Gangetic system
5:00-5:15	S1.09	Behera, S.K.	Indicator species (Gharial and Dolphin) of Riverine Ecosystems: An exploration of River Ganga
5:15-5:30	S1.10	Sarkar, U.K.	Sustaining freshwater fish biodiversity and aquatic ecosystem in the tributaries of Ganges basin: Pattern, importance, biogeography and future challenges
5:30-5:45	S1.11	Aftabuddin, Md.	Effect of river connectivity on the ecology, biotic community and fisheries of wetlands
5:45-6:00	S1.12	Samanta, S.	Metal and pesticide pollution scenario of River Ganga
6:00-6:15	S1.13	Manna, R.K.	Irresponsible fishing in Hooghly estuary: A major concern for sustainable fisheries
6:15-6:30	S1.14	Roshith, C.M.	Ichthyofaunal diversity, assemblage structure and seasonal dynamics in the freshwater tidal stretch of Hooghly estuary along the Gangetic delta

Saturday, January 5th			
Session 2.	**Major Rivers**		
6:30-6:45	S2.01	Das, M.K.	Patterns of fish diversity, community structure and ecological integrity of River Yamuna, India
6:45-7:00	S2.02	Joshi, K.D.	Piscine diversity and fisheries in the river Yamuna - Present status
7:00-7:15	S2.03	Nath, P.	The value of inland waters in the Brahmaputra River System with special reference to Arunachal Pradesh
7:15-7:30	S2.04	Joshi, K.D.	Studies on Impact assessment of inter-linking: A case study in the Ken and Betwa rivers (India)
7:30-7:45	S2.05	Singh, H.	Status, threats and conservation challenges to key aquatic fauna (crocodile and dolphin) in National Chambal Sanctuary, Madhya Pradesh, India
7:45	**End of day**		

Sunday, January 6th			
Session 2.	**Major Rivers, Continued**		
2:00-2:15	S2.06	Manna, S.K.	Enzymatic characteristics of river Damodar
2:15-2:30	S2.07	Jha, B.C.	Impact of dams on the ecology, biodiversity and fisheries of rivers, including the Ganges
2:30-2:45	S2.08	Bhaumik, U.	Ecology and fisheries vis-à-vis dams: a case study of the Narmada river system in India
2:45-3:00	S2.09	Das, A.K.	Status of river Krishna - water quality and riverine environment in relation to fisheries
3:00-3:15	S2.10	Krishna Rao, D.S.	Biology of Deccan Mahseer, *Tor khudree*, from upper stretch of River Cauvery, Karnataka, South India
3:15-3:30	S2.11	Bhat, A.	Conservation strategies for tropical river systems: A case study from fish assemblages of the Western Ghats
3:30-3:45		**Tea break**	
3:45-4:00	S2.12	Ahmed, Z.F.	Stock assessment and management of Hilsa Shad *Tenualosa ilisha* in the Meghna River system in Bangladesh
Session 3.	**Socio-economic Perspective**		
4:00-4:15	S3.01	Nautiyal, P.	Comparing species richness in the Himalaya to the Gangetic Plains: the wrong precedent for Environmental Impact Assessments
4:15-4:30	S3.02	Mohanty, B.P.	Biomarkers for pollution monitoring in tropical rivers - trends and prospects
4:30-4:45	S3.03	Sahoo, A.K.	Environmental flows for sustenance of a river ecosystem - A case study with special reference to fish
4:45-5:00	S3.04	Kumar, R.	Longitudinal and temporal patterns of zooplankton distribution and community structure in the Vikramshila Gangetic Dolphin Sanctuary, Bihar, India
5:00-5:15	S3.05	Prakash, D.	Longitudinal and temporal patterns of the Macro-benthic invertebrate community structure in the Vikramshila Gangetic Dolphin Sanctuary, Bihar, India
5:15-5:30	S3.06	Singh, S.N.	Development of Decision Support System (Dss) for environmentally degraded river system on the west coast of India through Bayesian Belief Networks (Bbn) based modelling
5:30-5:45	S3.07	Katiha, P.K.	Socio-economic status of riparian fisher community in India
5:45-6:00	S3.08	Sinha, A.	Community empowerment for improved livelihood and ecosystem management
6:00-6:15	S3.09	Roy, A.	Socioeconomics of Fisherwomen of Hooghly Estuary- A Case Study

Sunday, January 6th			
6:15-6:30	S3.10	Katiha, P.K.	Institutional Arrangements in Fisheries of Ganga River System
6:30-6:45	S3.11	Nowsad, A.	Post-harvest quality of river shad *Tenualosa ilisha* in retail distribution obtained from Padma-Meghna confluence in Bangladesh
6:45-7:00	S3.12	Dubey, P.	Air-breathing fishery and their sustainable development of Kosi region, North Bihar with reference to economic development of rural inhabitants
7:00-7:20	**Panel Discussion**		
7:20-7:30	**Book Publication Plans**		
7:30	**Adjournment of symposium**		

Keynote Abstract

MUNAWAR, M.[1,2], MANDRAK, N.E.[1], MINNS, C.K.[1], LORIMER, J.[2], FITZPATRICK, M.[1]

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Freshwater Fishes and Fisheries of the World: Health, Biodiversity and Management

Freshwater resources are gaining increasing attention in the 21st century. Human use and abuse of freshwater resources is growing uncontrollably. The issues of conservation and protection of biodiversity are gaining worldwide attention. Freshwater fishes are especially important since they often serve the dual roles of major food source and indicators of ecosystem health. The Aquatic Ecosystem Health & Management Society (AEHMS) launched an ambitious initiative focusing on Freshwater Fishes and Fisheries of the World. The AEHMS has been developing a series of publications to raise awareness of freshwater fishes, habitats, and fisheries in all regions of the world including: North America, South America, Europe, Scandinavia/Baltic, Russia, Africa, Middle East and the Indian subcontinent. This is a long term project which consists of publishing papers on various regions/countries, as they become available, in the journal *Aquatic Ecosystem Health & Management*. From these peer-reviewed papers, we intend to publish a holistic and integrated synthesis of the state of the world's fisheries as part of the Ecovision World Monograph Series. This global initiative is progressing steadily and several papers have been published from a variety of countries including India, Australia, New Zealand, Greece, Scandinavia, Nepal, Peru, and Mexico. Currently, the AEHMS is actively collaborating with CIFRI, Barrackpore on two major projects: 1. Health and Fisheries of the Major River Ecosystems of India and 2. Ecosystem Health and Management of the River Ganga. Both of these peer reviewed books will provide the most up to date, top down overview of the health, biodiversity and management of the Indian Rivers. Information about *AEHM* and publications is available on the website of the AEHMS (www.aehms.org) and Taylor & Francis (www.tandf.co.uk/journals/tf/14634988.html).

Abstracts

List alphabetically by presenting author

AFTABUDDIN, MD.[1], HASSAN, M.A.[2], DAS, A.K., JHA, B.C., SHARMA A.P.

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Effect of river connectivity on the ecology, biotic community and fisheries of wetlands

Wetlands associated with the floodplains of the Ganges and Brahmaputra river systems cover an estimated area of 2, 00,000 ha and play a vital role in fisheries, rural economy and environment stabilization. In recent years, a majority of wetlands in Bihar, Assam and West Bengal are losing connectivity with their parent river due to natural and anthopogenic drivers, causing rapid shrinkage of valuable wetland resources and threatening their biodiversity and ecological function. Connectivity of wetlands with parent river is of special significance to the ecology, biodiversity and fisheries of the ecosystem. The present study was conducted to assess the effect of river connectivity on the environment, nutrient profile (including its regeneration potential in water and soil), abundance and diversity of biotic communities including fisheries. Four wetlands, two open and two closed from the Ganges and Brahmaputra basins were selected for this study. Comparative analysis of two ecologically distinct wetlands of the Ganges basin, revealed more seasonal water depth decrease, higher water conductivity and nutrients (Ca^{+2}, Mg^{+2}, SiO_3-SiO_2), higher sediment microbial activity, phosphorous cycling and carbon cycling enzymes, organic matter, conductivity, oxidation reduction potential and more abundance of plankton and macrobenthos in closed than open wetlands. However open wetlands showed more diversity of plankton and macrobenthos. The profound impact of connectivity on wetland fisheries was observed in wetlands ecosystem of the Brahmaputra basin in Assam showing higher catch percentage of auto-stocked indigenous fish species with more fish yield in open than closed wetlands. Due to lack of river connectivity, closed wetland, therefore, reduces diversity of the biotic communities and clearly demonstrates deleterious impacts on natural fishery necessitating stocking enhancement as the inevitable means to sustain its fishery. Therefore, restoration of link channels to parent rivers would be the immediate need to maintain the biodiversity and productivity of closed wetlands.

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Stock assessment and management of Hilsa Shad *Tenualosa ilisha* in the Meghna River system in Bangladesh

The research carried out investigations into the stock of riverine hilsa shad, *Tenualosa ilisha* and the implications for the sustainable management of this valuable fish species in Bangladesh. Commonly used models were employed to estimate values using 1200 specimens from monthly samples collected from Meghna River over a calendar year from January to December, 2011. Recruitment occurred at total length (TL) of ~19.25 and 23.64 cm, and at age of ~0.44 and 0.59 years for both males and females, respectively. An individual male reached a theoretical maximum TL of 41.88 cm, and a female 52.4 cm. Males grew faster than females early after birth and growth coefficients were 1.40 for males and 1.0 for females, per year. The asymptotic body weight for males and females were about 0.8 and 1.7 kg, respectively. The study confirmed spawning occurred all year, with peak spawning in October. The minimum TL of a spawning female was 19.5 cm, and the mean TL at first sexual maturity was 22.70 cm. The species reproduces by synchronous iteroparity, with a mature female spawning once during a spawning season. The fecundity was from about 69,204 to 16,77,027 eggs in terms of total length while it ranged from about 48,446 to 14,11,606 in terms body weight. The Meghna hilsa shad population suffered from high mortality in 2011. The natural and fishing mortalities for males were 2.12 and 1.32 per year, and for females were 1.52 and 2.57 per year, respectively. The maximum yield per recruit obtained for males was 89.76 g at fishing mortality of 2.0 per year, and for females was 338.18 g at fishing mortality of 1.5 per year. The biomass analyses, however, suggested that males attained about 106.29 kg at the age of 0.75 years while females attained 172.36 kg when they were 1.08 years old, if 1000 individuals of each sex were recruited to the *T. ilisha* adult stock in Meghna River. Eventually output parameters obtained in this study were used to write a simple management guide for the *T. ilisha* fishery in the Meghna river system in Bangladesh.

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Indicator species (Gharial and Dolphin) of Riverine Ecosystems: An exploration of River Ganga

The Ganges River sustains a diverse group of flora and fauna including the endangered Ganges river dolphin (*Platanista gangetica gangetica*) and critically endangered gharial (*Gavialis gangeticus*). Because of the high productivity and population there is a strong demand for natural resources, which threatened the survival of indicator species like gharials and dolphins in river Ganga. There are several riverine indicator species which are threatened by human activities in the Ganga basin. However, the Ganges river dolphin and gharial are reliable indicator species. Studying indicator species could create the basis of a sustainable research programme to see how changes in the species can be related to the health of the river system. This would help to implement various programmes for restoration of the river system. Human perturbations and anthropogenic disturbances have led to drastic declines in dolphin and gharial populations over much of their distribution ranges during the last several decades.

However, due to active involvement of WWF-India in dolphin conservation in certain areas, the recent survey reported interesting trends in terms of a stable dolphin population. Stretches that reported stable dolphin populations were areas where there had been some interventions taken by local communities, forest departments, and other non government organizations.

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Conservation strategies for tropical river systems: A case study from fish assemblages of the Western Ghats

While freshwaters (rivers, lakes, and wetlands) comprise less than 0.01% of the total surface water on Earth, they are amongst the most diverse of ecosystems. However, freshwater species and habitats are also among the most threatened in the world. It is projected that habitat losses will lead to significant declines in freshwater fish diversity-rivers that are expected to lose fish species are concentrated in poor tropical and sub-tropical countries. The freshwater diversity of the Western Ghats (one of the global biodiversity hotspots) is particularly vulnerable to recent expansion of human population and development in the region. Unfortunately their fauna are also among the least studied taxa and information on their species distributions is sparse and patchy. The present study is an example of how baseline data on fish assemblages in disturbed and undisturbed river systems of the Western Ghats can be employed in developing conservation prioritization plans for tropical river systems. Analyses of beta diversity patterns along river gradients indicate the sensitivity of species turnover to altered habitats and polluting industries near study sites. Null model analyses to investigate assemblage structure across disturbed and undisturbed sites on the rivers further reveal that structure of species co-occurrences also appears to be dependent on the extent of human disturbance on these rivers. A method of ranking based on the Index of Biotic Integrity (IBI) was used to categorize sites based on their disturbance levels. These studies, along with information on regional effects of disturbance would help provide a better understanding of the structure and dynamics of species composition. A combination of these approaches should be used in developing conservation strategies for the region and prioritization plans for management at local as well as regional scales.

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Ecology and fisheries vis-à-vis dams: a case study of the Narmada river system in India

Narmada, the oldest river system in India, originates from Amarkantak in Madhya Pradesh, flows east-west and flows into the Gulf of Cambay in the Arabian Sea. The river drains an area of 45.64 km^3. A series of dams was proposed to hold water for multiple uses. So far, three dams have been erected in Madhya Pradesh and one is under construction in Gujarat. A comparison of pre and post impoundment eco-environment and fisheries revealed changes in water quality, productivity and aquatic flora and fauna of the river system. Among the fishes, species like *Tor tor*, *Labeo fimbriatus* and *Labeo dyocheilus* were most affected. The ratio of carp, catfish and miscellaneous groups has significantly changed indicating a fall of 17%, 36% and an increase of 410%, respectively. The catches of *Macrobrachium rosenbergii* and *Tenualosa ilisha* have also declined by 46% and ~300% in the estuarine stretch of the river system. Suitable conservation measures for nourishment and development of the fishery have been suggested.

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Fisheries of Indian Shad (*Tenualosa ilisha*) in the Indo-Gangetic system

Tenualosa ilisha, the Indian shad, has established itself as one of the most important commercial fishes of the Indo-Pacific region. The hilsa fishery in India and Bangladesh is dependent on the single species, namely *Tenualosa ilisha*, belonging to the Indo-Gangetic and Brahmaputra river basins. In India the fishery resource of the species largely lays in the Bhagirathi-Hooghly component of the Ganga river system. The annual fish catch of hilsa from the Bhagirathi-Hooghly river system fluctuates greatly over the years. Hilsa landing in the Bhagirathi-Hooghly river system during 2000-01 to 2010-11 ranged between 12,733 and 77,912 t. Low salinity is ideal for breeding and maturing hilsa. The hilsa catch consisted of a wide size range (length/weight) of fishes. The maximum catch was comprised of 270-300 g. Monsoon migration of hilsa commenced in July and gradually picked up in August. From September onwards the magnitude of migration was highly variable with a declining trend. Stretches between Nischintapur and Diamond Harbour in the downstream region, Hooghly ghat and Kalna in the freshwater tidal zone and Lalbagh to Farakka in Bhagirathi River could be demarcated as potential breeding zones for hilsa. A mixed population of fry to juveniles (26-163 mm) was available almost year round with spatio-temporal variability in size and density. The intensive fishing pressure in the coastal marine zone almost all year, especially in breeding season, adversely affect the breeding migration, spawning, spawning and recruitment success and overall fisheries of hilsa. Under-sized fishing through small meshed gill nets and unwanted hauling of the juveniles were observed as major anthropogenic factors affecting the migration, spawning and recruitment success of hilsa. There is an immediate need to formulate effective measures and also by-laws to protect precious breeders and potential breeding grounds for development of a sustainable hilsa fishery.

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Vanishing fish habitats of River Ganga

The Ganga river system is one of the biggest inland capture fisheries of the world. The ecosystem contributes significantly to the total fresh water fish production of India. It is estimated that more than 265 species of inland fishes are available in river Ganga. The ecosystem is not only the habitat of cold water fishes but potential fishing grounds of warm water fishes like carps, catfishes, snakeheads, feather backs, hilsa and freshwater prawns. The ecosystem plays a vital role in the food, nutritional and economic security of the country.

During the past few decades, significant morphometric and hydrological alterations have occurred, mainly due to alteration in flow regime, river course diversion, excavation of river bed for sand and silt, and water abstraction. Discharge of untreated urban sewage, pesticides, industrial effluents and toxic materials have significantly changed the qualitative and quantitative features of fish habitat, which in turn have not only created uncongenial conditions for fish life but have also destroyed innumerable breeding, spawning and feeding grounds for many valuable fishes. As a consequences of destruction of fish habitat the lucrative fish yields of migratory fishes, namely mahseer, snow trout, hilsa, fresh water prawns, as well as commercially important fishes like major carps, catfishes, feather backs and freshwater prawns, have declined from their previous bountiful state and in the last few decades have become under the threat of extinction.

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Status of river Krishna – water quality and riverine environment in relation to fisheries

River Krishna is the second largest peninsular river of India after Godavary, with the highest drainage area (268,786 km^2), 25.8% in Maharashtra, 42.4% in Karnataka and 31.8% in Andhra Pradesh. Originating in the Mahabaleswar hills (1337 m asl) of the Western Ghats in Maharashtra, it traverses 1400 km in a west-easterly direction covering Maharashtra, Karnataka and Andhra Pradesh before being emptied in the Bay of Bengal (BOB). The water flow is occassionally obstructed by five major reservoirs, though the river is fed with more than 32 tributaries. Krishna receives run-off water from its catchment and a mean rainfall of 1510 mm, the run-off contribution per unit of catchment is about 0.250 MCM/km^2. The river was explored from origin to confluence at BOB (into two stretches) to unravel its limno-chemical profile, pollution scenario, fish species composition, abundance and fish bio-diversity. Data thus collected was processed through different statistical tools to discover relationships with the abiotic parameters, productivity and the fish species. Water and sediment quality parameters revealed that the river is one of the most productive rivers in India as validated by its alkalinity, hardness, and water & sediment pH being reflected in primary production. Most of the tributaries showed productive criteria contributing enormously to the limno-chemical characteristics of Krishna. Local pollution was phenomenal as revealed by chloride content in some of the tributaries, especially in the first monsoon flood. The fish catch in the entire Krishna system has been dwindled drastically with a great reduction in catch structure as well as faunistic diversity. More catches are available around areas of reservoirs, anicuts and dead weirs due to stagnation with more congenial ecology for fish survival. Species diversity and richness were both lowered in the lower stretch in this study compared with the upper stretch. More species was encountered in the upper and middle stretch compared to downstream. This might be due to the positive influence of reservoirs connected with the numerous tributaries in this region coupled with the existence of more open river, slow water and pool habitats along with macrophytic abundance which might have exerted influence in fish assemblage and aggregation. The study is a modest attempt and will be immensely helpful in unravelling the various facets of riverine ecology and their bearing of productivity, fish bio-diversity, species abundance and overall riverine health.

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Patterns of fish diversity, community structure and ecological integrity of River Yamuna, India

River Yamuna, one of the most important and sacred rivers of northern plains of India, is highly polluted. The river originates from the Yamunotri glacier and traverses 120 km to emerge into the Indo-gangetic plains at Dak Pathar in Uttaranchal and finally joins Ganges river at Allahabad, traversing 1376 km. The aim of the study was conducted during 2007-2010 to assess the fish diversity, community structure and ecological integrity in the 1200-km stretch of the river Yamuna from Dak Pathar to Allahabad. The water quality reflected an alkaline pH (7.6-8.0). Dissolved oxygen was optimumal at all the sites (7.3- 9.8 mg l^{-1}) except at Wazirabad and Agra (3.4-3.7). 143 fish species were recorded from the river. Cyprinidae was the most abundant family followed by Schilbeidae Bagridae and Sisoridae respectively. The abundance distribution of species indicated dominance of 48 species, with around 250 numbers. The highest species similarity was recorded between Yamunanagar-Panipat, followed by Wazirabad - Hamirpur and Yamunanagar -Allahabad. The middle stretch of the river exhibited dominance of small bodied erytopic, indigenous and exotic fish species with periodic and opportunistic life history strategies and a significant decline of the large bodied prized Indian Major Carps. A tropic shift towards the dominance of carnivore catfish species is evident. Multivariate analysis revealed 83.50% of the total variability in species composition patterns in the river along the gradient of the river could be attributed to the environmental variables: dissolved oxygen, turbidity, conductivity, total dissolved solids, stream velocity and water temperature as the most important variables for fish assemblage in river Yamuna.

Inadequate flow in the middle stretch of the river has altered the fish habitat availability of the fishes resulting in changes in fish composition and assemblage patterns. The study would help future efforts for conserving the aquatic communities and their habitats in the river.

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Fish diversity, community structure and ecological integrity of the tropical river Ganges, India

The river Ganga is one of the largest river systems in the world, sustaining a rich biodiversity of fish and fishers. In recent years, a decline in fish diversity and catch is discernible due to various anthropogenic activities in the river basin. The present study makes a comparative analysis of the time series data on environmental quality and fish diversity to evaluate the ecological integrity of the river at present. The comparative assessment of water quality indicates conducive levels for fish, but sediment quality reveal a sandification of the river bed in the middle stretch. Literature records 265 species for the Ganga basin. However, species accumulation plot shows that there might be 331 species in the basin indicating that 20% of species have not been recorded to date. Cyprinidae was the most dominant family with predominance of small bodied fish species in the entire upper, middle and lower stretch of the river. Decline in the Indian major carps (IMC*) C. catla, L. rohita* and *C. mrigala* is reflected by their low relative abundance (0.02-0.24%). Significant alteration in fish catch composition is evident from 1961 to 2010 in the middle stretch at Allahabad where the yield declined from 935.4 kg km^{-2} to 398 kg km^{-1} in 2008 but increased to 733 kg km^{-1} in 2010. The catch composition during the period reflected a progressive decline in IMC and *Tenualosa ilisha* but with a significant increase in exotic fish *C. carpio* and *O. niloticus* contributing 43-48% to the total catch. Index of biotic integrity assessment showed 35% of the studied sites of the river supported fish assemblage in acceptable condition. An effective management strategy for sustainable management of the river Ganga is suggested.

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Air-breathing fishery and their sustainable development of Kosi region, North Bihar with reference to economic development of rural inhabitants

The present study attempts to describe the water resources and the role of sustainable development of the air-breathing fishery for socio-economic upliftment in rural areas of the Kosi region of Bihar. The water bodies of the Kosi region are generally teeming with rich vegetation and are considered natural habitat for air-breathing fishes. Air-breathing fishes are very nutritive, and are therefore of commercial and therapeutic importance. It was found that the air-breathing fishery of Bihar is based on highly traditional methods, generally on capture fishery. An attempt has been made to study the socio-economic conditions of fishermen in Kosi region. It was found that there is a great need of financial assistance, technological awareness, mitigation of complications for the lease of water bodies/jalkars, transportation, preservation and marketing facilities for the sustainable development of the air-breathing fishery in this region.

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Algal biodiversity in the lower stretch of River Ganges

The lower stretch of River Ganges drains the Bhagirathy-Hooghly river complex (210°50'-220°15' E and 870°45'-880°15' L). In recent times it has been subjected to various threat perceptions, especially due to the construction of Farakka barrage which regulates the freshwater discharge to a large extent. It receives most of its sediment supply from River Ganges during the Southwest monsoon. The offshore part of the estuary experiences high tidal ranges and strong winds, extending to a distance of 80 km south of Sagar Island. The Hooghly-Matlah estuarine system also has the distinction of nurturing the largest mangroves of the world with distinct wetlands supporting huge aquatic biodiversity including the algal flora. The lower Ganges, including the Bhagirathy, contains a sizeable freshwater stretch, to the extent of more than 250 km, providing additional niches for the colonization of freshwater algal flora.
A detailed study on algal biodiversity of the system was conducted from 2000-2003. A total of 503 algal species were collected, identified, and photographed leading to the preparation of a comprehensive inventory of algae, from the freshwater stretch to near a marine environment. Distribution and abundance of algae were also observed in relation to varying salinity regimes as well as other water quality parameters. The distribution of algal species across the length of the stretch indicated a definite pattern, such as greater dominance of oligohaline species in the freshwater regions, mesohaline species in low or medium saline zones and polyhaline species in high saline zones. A large number of algal species, however, were urohaline in nature, withstanding a wide range of salinity fluctuations.

The algal spectrum of the stretch indicated the dominance of Bacillariophyceae (59.25%) followed by Chlorophyceae (16.50%), Cyanophyceae (14.80%), Euglenophyceae (7.03%), Dinophyceae (3.64%), Xanthophyceae (1.22%), Rhodophyceae (0.72%) and Pheophyceae (0.48%) in terms of species diversity.

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Impact of dams on the ecology, biodiversity and fisheries of rivers, including the Ganges

India, by virtue of its geographical location, is bestowed with plentiful and diverse aquatic ecosystems, including a large number of river systems. In recent times however, most of the river systems in the country, including the Ganges, are in a critical stage of ecological transition. Post independent India has witnessed the emergence of a large number of dams across various rivers, which harness the water for irrigation and hydro-electric power. This singular factor has thus been identified as one of the principal causative factors for bringing aberration in ecology, biodiversity and fisheries.

The biodiversity and fisheries of the affected rivers have undergone significant changes. There has been an appreciable shift in biodiversity, including in the fish fauna upstream as well as down from the dams, primarily due to fragmentation of the flow regime.

In the context of the aforesaid data generated from a number of rivers, both during the pre and post impoundments and with regards to fish diversity and the status of breeding biology of commercially important fish species, the impact of dams on fish and fisheries were investigated.

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Piscine diversity and fisheries in the river Yamuna – Present status

The River Yamuna originates from the Yamunotri in the Greater Himalayas of Uttrakhand and debouches into River Ganga at Allahabad. Yamuna is the largest tributary of the river Ganga.

Fish biodiversity of the river was studied during 2010-12 at different centers between Badwala (Dehradun) and Arail (Allahabad). A total of 113 fish species belonging to 75 genera, 26 families and 10 orders constituting nearly 43% of fish biodiversity of Ganga river basin has been recorded. Among these, 6 species were exotic. Cyprinids were the dominant group represented by 47 species belonging to 26 genera, followed by Sisoridae (5 genera and 8 species), Bagridae (3 genera and 7 species) and Schilbeidae (6 genera and 7 species). Out of 113 species, 5 were categorized as Not Evaluated, 4 Data Deficient, 90 Low Risk, 10 Nearly Threatened, 4 Vulnerable and 1 Endangered; hence about 13 % of species are among the list of threatened fishes. As per trophic structure of the river ecosystem, the omnivore fishes were predominant (79%), followed by herbivorous (13%) and carnivorous fishes (8%).

Indian Major Carp (IMC) fishery has declined, while the exotic species, especially the *Oreochromis niloticus niloticus* and *Cyprinus carpio*, are increasing at an alarming rate in the entire stretch posing threats to trophic structure and ecological stability. Commissioning of the Farakka barrage has adversely impacted the migratory route of anadromous *Tenualosa ilisha* and the catadromous *Anguilla bengalensis bengalensis*. Hilsa fishery has nearly been entirely wiped out from the Yamuna. Obstructions in river course, abstraction of the water and addition of pollutants have adversely impacted the IMC, Catfish, other carps, miscellaneous fish and potamodromous fish like *Tor tor*, T*or putitora* and *Bagarius pagarius*.

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Studies on Impact assessment of inter-linking: A case study in the Ken and Betwa rivers (India)

The Ken and Betwa rivers are the major tributaries of the river Yamuna. Both rivers originate above 550 msl in the Vindhya region; hence represent almost similar morphometric, geographic and ecological conditions. The Betwa and Ken ivers traverse 590 km and 427 km respectively, through diverse catchments covering forest, agricultural fields, human settlements, pasture lands and finally debouch into the river Yamuna. An inter-linking project is proposed in the rivers which envisages a diversion of surplus water from the Ken basin to the water deficient Betwa. As a result of varied and diverse habitats, the rivers harbour rich piscine diversity. A total of 89 fish species belonging to 10 orders, 26 families and 62 genera have been recorded from the Ken, and 81 species classified under 10 orders, 24 families and 55 genera from the Betwa. Exotic fish species were also observed in downstream stretches of both the rivers. Of the total fish species, 76 were common in both rivers, 12 were found only in the Ken and 5 species were restricted to the Betwa. Analysis of relative abundance showed dominance of *Labeo boggut* in the river Ken and *Osteobrama cotio* in the Betwa. A total of nine near threatened fish species were recorded from both the rivers.

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Socio-economic status of riparian fisher community in India

The inland traditional fishers are primarily dependent on natural waters for their livelihoods. Despite efforts of Central and State Governments, production from most of the culture-based inland fishery waters is below potential, and for the capture fishery resources, it is declining. The impact of fisheries developmental programmes was hard to define for this community due to the multiple use common pool resource (CPR) nature of the resource. Comprehensive investigations of the socio-economic status of inland fisher communities are rare. That considered, the present investigation was undertaken to study the socio-economic conditions of riparian fisher communities in different regions of India.

The study covered 406 respondent households from North, South, East, West and North-East regions of India covering six states: Uttar Pradesh in North, Tamil Nadu and Kerala in South, Orissa and West Bengal in East, Gujarat in West and Assam in the North-Eastern region. Multi-stage stratified random sampling was adopted to select respondents. Primary data was collected using comprehensive and pre-tested questionnaires. The variables considered for the study were gender, age, literacy, health, employment, income and expenditure patterns. Overall socio- economic index results concluded that almost all the regions have achieved only 46 % to 52% of the socio-economic criteria.

Suggested measures for improving their livelihood options and to uplift socio-economic status are i) institutional financial support for alternate income generation activities; ii) organisation under Self Help Groups, iii) vocational training for fisherwomen to undertake household income activities during closed/off season, iv) creation of awareness about different government development and social sector programs v) provision of rural infrastructure for general societal/human development and vi) capacity building of community based fisheries.

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Institutional Arrangements in Fisheries of Ganga River System

The impact of institutional arrangements has been compared in three stretches under different management regimes namely, i) open access (river Ganga from Kanpur to Farakka), ii) private contractor (river Yamuna from Yamuna Nagar to Panipat), and iii) fishermen co-operative (river Ghagra from Ghagra Barrage to Faizabad). Ownership of these portions of the Ganga River system is held by: The Department of Fisheries, Forests, Revenue and the Viilage Panchayats under the Governments of the riparian states. In some cases ownership by more than one department exists along some stretches, resulting in more than one governing body fishing the area, handling conflicts among local fishers, and degrading the fish stocks.

The open access regime has no institutional arrangements; while for cooperative and individual/private regimes the river was leased for 3-7 years. The lease was generally renewed for fishermen co-operatives, but private contractors had more uncertainty due to bidding through an open auction system and rising base prices. Annual fishing efforts were at maximum and the probability of irrational exploitation was high under private regime as a result of the fishing practices adopted and a limited lease period. The equity issues were better in co-operative and open access regimes. Catch per unit effort was the highest under open access, while the costs were lowest for fisher co-operatives. Fish prices were higher for fish co-operatives due to better bargaining power and collective fish disposal and annual net returns were at maximum for fishers under open access, but, net returns per kg of fish produced and output – input ratios were the highest for fishers of co-operatives. Results indicated the highest working efficiency and equitable distribution of benefits under the co-operative regime.

The study concluded that involvement of actual fisher institutions in riverine fisheries may be encouraged for better fisheries management. Periodic evaluation of these institutional arrangements to assess their performance and natural resources use is highly recommended.

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Biology of Deccan Mahseer, *Tor khudree,* from upper stretch of River Cauvery, Karnataka, South India

This study was conducted during 2006-2008 and gives an account of some biological aspects of the Deccan Mahseer, *Tor khudree*, a large riverine cyprinid in the upper stretch of the river Cauvery, Karnataka, South India. Mahseers are locally important as food fish and world famous as game fish. Mahseers prefer highly oxygenated, fast moving, clear waters with rapids and riffles.

Although Mahseers occur at several reaches in the upper stretch of the river Cauvery, three reaches are important from the abundance point of view: Kushalnagar (Walnoor to Kushalnagar), Ramanathapur and Bheemeswari (Shivasamudram falls to Mekedatu). Meristic counts were recorded and the relationships between morphometric characters were estimated. The relationship of length with weight, body length with gut length, body length with scale radius, body length and weight with fecundity were estimated. Scales were used for age determination.

Tor khudree is a bottom feeding omnivore and feeds in the marginal areas. Principal food items recorded were plant materials (seeds and debris, aquatic macrophytes), aquatic insects and molluscs (mainly gastropods). Fish and crabs were recorded in low density only in larger fish (more than 50 cm length).Growth parameter $L\infty$ was 90.44 cm and K was 0.27. The overall sex ratio was 1.09 (48% males and 52% females). Breeding season is protracted and extends from August to late November. Fecundity ranged from 2,402 in fish of 410 cm length to 30,511 in fish of 90.0 cm. Destruction of juveniles and brood fish is rampant. Recommendations are given for conservation.

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River Ganga – historical, cultural and socio-economic attributes

Ganga is a symbol of faith, hope, culture, sanity and source of livelihood for millions since time immemorial. She is the centre of social and religious tradition in the Indian sub-continent and particularly sacred in Hinduism. The very special faith and respect for river Ganga in India are as old as Indian culture itself. These are amply reflected in ancient Indian scriptures *Vedas, Puranas, Mahabharata, Ramayana* as well as in several others. In fact, the respect for Ganga is a part of 'Indian Identity' and the very symbol of 'Indian Culture'.

The history of Ganga in nurturing culture and civilizations is appreciated through fostering native culture in its basin, shifting of the Indus-Sarasvati basin civilization into its fold and promoting an integration of cultures to develop Indian civilization. The Ganga alone drains an area of over a million square km. Its extensive basin accounts for one-fourth of India's water resources and is home to more than 407 million Indians - or one third of India's population. Its fertile soil is a significant contributor to the agricultural economies of both, India and Bangladesh and its tributaries provide a perennial source of irrigation to a large area as well as recharging the ground water table all along its course.

By supporting agriculture, animal husbandry, fisheries, tourism, river based trade and transport, etc., the river contributes significantly to livelihood, food and nutritional security for nearly one third of Indians and two thirds of the Bangladeshi population. This paper attempts to present a macro view of the Ganga and set a broader context encompassing its historical, spiritual, cultural and socio-economic attributes which remain often untouched in scientific papers.

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Patterns in zooplankton community structure and distribution along the Patna to Chak (Begusarai) stretch of the River Ganga in Bihar

The Ganga ecosystem provides a distinctive pattern of distribution of the riverine communities existing therein. Study of the species richness in rivers is more complete for vertebrates than for invertebrates. Among invertebrates, zooplankta are lesser explored groups. Being bacterivorous and algaevorous, and constituting preferred food for macro-invertebrates and planktivorous fishes, zooplankton plays a central role in carbon transfer.

The present study was conducted to analyse the abundance, distribution, and diversity of zooplankton collected at 18 stations in the heterotrophic Meta-Potamon portion extending from Patna through Chak (Begusarai) covering a 114 km stretch of the river. Zooplankton samples were taken by filtering 100l of river water thorough a 53 µm mesh net. Besides selected water quality parameters, Chl a content and qualitative analyses of phytoplankton were done at each station. In total, 12 zooplankton groups including ciliates, rotifers, cladoceran and copepods were identified. Both diversity and density of rotifers were higher at site I (Patna). The rotifers, mainly brachionids, were abundant at the right bank of the River at Patna station. The lowest zooplankton abundance was found at Barh stations, whereas at Makama stations rotifer populations were moderately recorded. Rotifers were mainly dominated by the genera *Brachionus* and *Filinea* whereas the predatory rotifer *Asplanchna* was present at all stations.

The zooplankton abundances and distributions were highly variable among stations, indicating a highly fluctuating ecosystem. Zooplankton abundances were not correlated with chlorophyll a levels. Hierarchical classification revealed higher temporal variability in the occurrence of cladocerans and copepod species; at the 1st hierarchical level, samples collected during 24-25 November were completely separated from other samples. Among these groups upstream station 1 was exclusively represented by the diaptomid calanoid copepods and brachionid rotifers. In Protozoa *Arcella* and *Centropyxis*, in Rotifera *Brachionus*, *Keratella* and *Testudinell*a in Cladocera *Daphnia, Bosmina, Moina* and *Ceriodaphnia*, in Copepoda *Nauplius*, *Cyclops, Mesocyclop*s and *Diaptomus* were abundant and dominant species at all stations sampled. However, species composition varied significantly at different stations. Of all the sites studied, stations at Chak- Ghat were recorded with maximum standing crop and taxonomic diversity of zooplankton taxa in comparison to other stations. The possible cause is the capacity of the rivers recovery potential along the considerable distance (114 kms) downstream from Patna to Chak-Ghat.

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Longitudinal and temporal patterns of zooplankton distribution and community structure in the Vikramshila Gangetic Dolphin Sanctuary, Bihar, India

The Vikramshila Gangetic Dolphin Sanctuary covers a 50-km stretch of the main channel of the Ganga River in Bhagalpur district extending from Sultanganj to Kahalgaon. It is the only protected area for the endangered Gangetic dolphin (*Platanista gangetica*) in Asia. The Sanctuary supports rich faunal diversity including many threatened aquatic wildlife such as the Indian smooth-coated otter, gharial, freshwater turtles etc. We conducted a yearlong study from January to December, 2009 to assess the community structure and temporal succession patterns of zooplankton at three sites (Sultanganj, Bhagalpur and Kahalgaon) in the Vikramshila Gangetic Dolphin Sanctuary. A total of 43 micro and meso zooplankton species including heterotrophic protists, rotifers, cladocerans and copepods were identified from 36 samples. The dominant zooplankton included Copepodids, Copepod nauplii, *Brachionus caudatum*, *Ceriodaphnia rigaudi*, *Mesocyclops leuckarti*, *Ceriodaphnia reticulata* and *Brachionus falcatus*. However, species composition varied significantly at the three sites. The nonmetric multidimensional scaling and cluster analyses revealed distinct seasonal and spatial variations in species dominance patterns. The first hierarchical level separated species occurring at Sultanganj from the other assemblages. The second hierarchical level distinguished species assemblage occurring in August – October 2009 at Kahalgaon. The samples in the remaining groups segregated on the basis of seasons. Indicator species among each cluster were identified by using an Indicator Index Value. The top three highly indicative species at Sultanganj were *Ceriodaphnia reticulata*, *Daphnia pulex* and *Brachionus quadridentatus* throughout the year. During monsoon season, the top three indicator species were *Ceriodaphnia rigaudi*, *Mesocyclops leuckarti* and *Brachionus falcatus* at Bhagalpur whereas at Kahalgaon the top three indicator species were developmental stages Copepods, *Brachionus caudatus*, and *Keratella tropica*. Mesocyclops sp., developmental stages of Copepods and *Daphnia carinata* were dominant in winter and *Moina* sp., *Ceriodaphnia rigaudi* and *Mesocyclops leuckarti* were the top three species in summer at Bhagalpur as well as at Kahalgaon. Of all the sites studied, Kahalgaon had the highest taxonomic diversity of zooplankton. One possible cause is the potential capacity of the river to recover downstream from Sultanganj to Kahalgaon.

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Irresponsible fishing in Hooghly estuary: A major concern for sustainable fisheries

Hooghly estuary, the lowermost 300 km stretch of river Ganga in India is well known for its wide range of fish diversity including freshwater, estuarine as well as marine fishes. A seasonal study was conducted during 2010-12 along the entire stretch of Hooghly estuary to understand fish species diversity and distribution in relation to environmental variables. Detailed analysis of different fishing gears in use revealed that most are highly destructive in nature since the catch was mainly composed of juvenile fish having no commercial value. Bag net (locally known as Binti jal) cod ends were pretty small and used to catch very small juveniles. At Diamond Harbour, bag net catch was dominated by juveniles of prized fishes like Tenualosa ilisha, Polynemus paradiseus, *Eleutheronema tetradactylum* along with a significant catch of juveniles of Otolithoides pama, *Coilia dusumeiri*, and *Harpodon nehereus*. Fishermen mainly earn money from the prawn component of the catch, whereas the major portion of fish catch was so small in size that it was purchased at throwaway prices by a local *Clarias gariepinus* culturist to feed the fishes reared in ponds. Charpata jal (Set barrier) is another destructive fishing gear which catches fish and prawn juveniles by its very small mesh of mosquito netting. Analysis of set barrier catch at Dakhineswar or Budge Budge in a freshwater stretch revealed the presence of very small (average size) fish species like *Glossogobius giuris*, *Gagata* sp., *Pisodonophis* sp. etc. besides juveniles of prized fishes like *T. ilisha*, *Setipinna phasa* etc. Use of shore seine (Ber jal) with mosquito netting at the freshwater stretch is also a concern for all locally available fishes like *Sicamugil cacasia*, *Setipinna phasa* etc. Different kinds of highly destructive shooting net (Meen jal) which target juveniles of prized prawn species like *Penaeus monodon*, *Macrobrachium rosenbergii* etc. in the lower estuary causes huge destruction of juveniles of many other prawn and fish species. Small mesh gill net (Chhandi jal) was also observed to catch juveniles of many prized fish like hilsa in the freshwater stretch. Modes of operation, area of operation, catch composition, seasonality, dimension, variability etc. of these fishing gears are discussed in the present communication. Restricted use of these fishing gears is urgently needed to revive the fishery of Hooghly estuary.

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Enzymatic characteristics of river Damodar

The majority of rivers in India are polluted, impacting the river's biotic community from bacteria to fish and higher order organisms. Microbial flora is also sensitive to pollution and terrestrial soil microbial activity is also impacted due to pollution. We have developed a rapid and sensitive fluorescence method for detection of water and sediment phosphatase, a key enzyme in phosphorus cycling, validated in river Damodar, to assess the impact of pollution on the enzyme activity using MUF-phosphate as a phosphates substrate. More than 3 years of study showed that the enzyme activity did not change significantly in the river water along the river course, but soil phosphatase activity decreased in the industrial areas, possibly as an impact of industrial pollution on the river soil microbial community. The microbial activity increased downstream at Jamalpur indicating recovery. The study showed that phosphatase could be a sensitive indicator of pollution in aquatic ecosystems.

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Biomarkers for pollution monitoring in tropical rivers - trends and prospects

Water is a prime natural resource and a basic human need. It is the most abundant compound on earth, covering about 70% of its surface in the form of saline water in the seas and oceans and freshwater in the springs, rivers, and reservoirs. However, the freshwater and marine systems have become the ultimate sink of both natural and anthropogenic chemicals into the environment. Along with the progressive chemical loading of aquatic environments there have been increasing attempts to develop methods for monitoring the pollutants and their biological effects. Aquatic pollution is a threat to health of organisms inhabiting the water bodies and the concern range from possible harmful effect on flora and fauna to possible harm to human consumers of such organisms. In order to prevent serious damage to the organisms or populations, early detection of pollutants is important. The need for early detection and assessment of the impacts of pollution in the aquatic environment has led to the development of biomarkers. Biomarkers are biochemical, physiological or morphological response of living organisms that may simply signify exposure to contaminants, may predict future harm or may themselves be harmful effects. Some of the biomarkers that have been used in international aquatic environmental monitoring programs include Cytochrome P-450 (CYP), acetylcholinesterase (AChE), metallothionins (MTs), δ-aminolevulinic acid dehydratase (ALAD), glutathione (GSH), malondialdehyde (MDA), HSP70. The recently developed omics (genomics, transcriptomic, proteomic and metabolomics) technologies have taken center stage in biomarker discovery and out of these proteomics (or ecotoxicoproteomics) has been a powerful technology in biomarker (predictive/prognostic/diagnostic biomarkers or surrogate end point) discovery. Using fish and shellfish as test animals, we are standardizing proteomic biomarkers in fish and shellfish tissues which could be suitable for pollution monitoring in the tropical rivers and other large aquatic ecosystems. We have analyzed the foot, gill and mantle tissues of bivalve molluscs, foot tissues of gastropods and blood plasma, liver, gill, muscle, lens proteins of fish employing standard proteomics techniques like 2-D gel electrophoresis, MALDI-TOF- Mass Spectrometry, LC-MS/MS, 2-D immunoblotting etc. in our ongoing efforts to standardize biomarkers suitable for biomonitoring the tropical rivers. We have standardized some biomarkers which are under validation.

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The value of inland waters in the Brahmaputra River System with special reference to Arunachal Pradesh

The North Eastern Region of India is drained by two major river systems. The Brahmaputra river system drains the northern part (Arunachal Pradesh & Assam) with 250 spp. of fishes, and the Barak Valley river system drains the southern part (Assam, Nagaland, Mizoram, Manipur, Meghalaya) with 100 spp. of fishes. These natural aquatic ecosystems have been the source of food for the majority of the rural population of this region from time immemorial. But it is a paradox of recent times that most of the inland waters are passing through a critical phase of ecological transition and that habitat destruction has threatened basic ecosystem functions. The impending crisis on biodiversity is likely to get worse with climate change and increasing incidences of invasive species. The paper portrays the values of inland waters and the potential threats posed by aquaculture and other industries with special reference to Arunachal Pradesh.

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Comparing species richness in the Himalaya to the Gangetic Plains: the wrong precedent for Environmental Impact Assessments

WII (2012) while performing cumulative EIA compared the fish species richness in mountain rivers systems Alaknanda and Bhagirathi with those of Gangetic Plains, two different biogeographic regions having different climatic conditions for their richness and faunal diversity. The report forwards an argument that these mountain rivers support low richness and also do not have premium species like dolphin and therefore hydropower projects can be developed even if it means the loss of aquatic biodiversity. It is surprising how this premier institute has ignored VEC (valued ecosystem component) guidelines. It seems the numbered items like apples, almonds or the snow leopard, musk deer, monal pheasant have no value compared with large volumes of wheat, rice, pulses, vegetables etc. produced in the Indo-Gangetic Plains. All these items grow in the mountains. Otherwise there is no reason to state that richness is high in the Plains where 140 species occur compared to 70 species in the whole mountain stretch. It seems that certain facts important to biodiversity have been either ignored or not considered. The purpose of this critique is to emphasize the ignored or overlooked facts pertaining to biodiversity.

The Himalayan mountain chains present extreme and harsh climate conditions in Greater Himalaya and a large part of the Lesser Himalaya by virtue of both latitude and altitude. This is in contrast to mild climate due to lower latitudes and altitude in the biodiversity hotspot Western Ghats. The life-forms that inhabit both land and water ecosystems in the Himalaya are unique and valued because they are specialists that have genes capable of adaptation to the harshest climate extremes and terrain. The Plains is endowed with a mild climate and hence more biodiversity. If it is a high diversity and species-rich zone why it has not been declared biodiversity hotspot? I also contest the strong correlation demonstrated between river flow and species richness and the statement that more species occurred in the Plains where the water flows are high, as not being a scientific argument. Why not measure the proportions of richness within that habitat? I suggest that if there are 70 species of fish in just 300 kms of mountain stretch, there should be 350 spp in 1500 km, but that is not the case since 140 species are present. Other related issues have also been discussed.

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Ecosystem health indicators in the Ganga Basin (Uttarakhand, India): Biodiversity and spatial patterns in structure and distribution of benthic diatoms, macroinvertebrates and ichthyofauna

This is a pioneering attempt to study spatial patterns in the structure of the lotic ecosystems of the Ganges River in the Himalaya. The diversity of sources (glacier fed, snow fed and spring fed) and stream-size (both interrelated) across the altitudinal panorama, create numerous habitats that contribute to structural diversity in mountains. The spatial patterns in richness, density and taxonomic composition and distribution of benthic diatoms are less affected by source waters compared with macroinvertebrates but there is a strong influence on the distribution of fish fauna especially poikiliotherms because a glacier fed river carries ice-cold waters. The abundance patterns of lower order organisms (diatoms, macroinvertebrates) do not differ sharply even across distant river basins as they are more influenced by proximate factors; thus there is notable resemblance between the distant SF Bemunda (lower Ganga basin) and SF Gomti (East Rāmgangā basin) and even the farthest Yamuna and Ramganga. Fish are more sensitive to temperature and current velocities that are related to altitude and hence respond to longitudinal rather than the spatial gradients. The lotic ecosystem of Doon Valley harbour rich and diverse diatom flora, macroinvertebrate fauna and ichthyofauna. The examination of trophic, saprobic and ecological status shows that organic pollution, degradation and anthropogenic eutrophication are non-existent in the Lesser Himalayan rivers and streams, but the fragile Doon Valley is under severe anthropogenic stress. This and habitats fragmented by the hydropower projects in the major rivers has threatened the iconic gamefish Himalayan mahseer in the Ganga.

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Post-harvest quality of river shad *Tenualosa ilisha* in retail distribution obtained from Padma-Meghna confluence in Bangladesh

The anadromous river shad hilsa, *Tenualosa ilisha*, is considered as one of the most tastiest fish. Bangladesh harvests nearly 60% of the world's hilsa. Hilsa is the 'National Fish' of the country and called "Macher Raja" meaning the king of fish. The upward migration of hilsa is restricted due to various man-made reasons, whereby the major catch is confined to the lower shore of Padma-Meghna confluence and adjacent brackish-water systems. In this study the post-harvest quality of Padma-Meghna estuarine hilsa destined for retail markets was investigated. Rigor-mortis was found to occur very early in hilsa, within 15-30 minutes of death. The fish achieved full rigor within 2 hours at ambient temperature (33°C) and rigor lasted for 16±0.4 hours. Fishing gears and harvesting period determined the initial quality of hilsa. Monofilament and other gill nets and set-bag nets deteriorated the quality. Hilsa with higher lipid content in pre-spawning catch got muscle deterioration earlier than those with lower lipid in post-spawning or lesser season (winter) catch. Hilsa was sold at a very high price, so better care was taken in post-harvest handling and marketing, unless a sudden glut catch disrupted ice supply and other facilities. Glut catch occurred once or twice in a year, mostly during September-October. Handling of hilsa on-board fishing vessel, at landing and in different steps of distribution and marketing was found to be adequate. Icing in traditional fashion was sufficient for market size hilsa, except during glut catch when ice supply could not meet the demand.

The majority of the hilsa were transported by bamboo baskets of different shapes and sizes usually with or without hogla mat or polythene covered and packed with sufficient ice. Hilsa landed in the Padma-Meghna confluence were transported by country boat. Other fish containers used were plastic drum, steel half-drum, hogla sacks and polythene sheet, aluminium container, wooden, fibre glass or plastic crates and Styrofoam. Hilsa was found to be handled very carefully during transportation and marketing, so spoilage or quality deterioration was not significant. The fish did not their quality when they were handled by fishermen, landing centers or commission agents in primary and secondary fish market. A 2% and 5% loss in hilsa destined for consumer market as wet fish were, however, recognized in landing centers and aratders. Glut catch of hilsa used for salt-curing suffered a substantial loss with the fishermen (14%) and at landing centers (43%).

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Longitudinal and temporal patterns of the Macro-benthic invertebrate community structure in the Vikramshila Gangetic Dolphin Sanctuary, Bihar, India

Because of the heterogeneity in benthic habitats the distribution of benthic invertebrates varies spatially and temporally. Macrobenthic communities may directly affect biogeochemical processes in the sediment and sediment stability while providing a coupling between meiofaunal and nekton communities and hence play an important role in structuring the riverine community. The present study investigates the longitudinal and seasonal distribution of macro benthic assemblages in the Vikramshila Gangetic Dolphin Sanctuary of the River Ganga. Samples were collected in June, September, December 2011 and in March 2012 covering a stretch of 60 kms at three sites in Vikramshila Gangetic Dolphin (*Platanista gangetica*) sanctuary from Sultanganj to Kahalgaon (Bhagalpur, India). Sampling stations were located along a gradient of macrophytic coverage in marginal water and sediment texture. At each of the three sites, 15 samplings were done in the recently exposed and submerged bottom sediment using a standard handnet with a mesh size of 300 μm. For each sampling, a stretch of approximately 10 m was sampled during 5 minutes. The sampling effort was proportionally distributed over all micro habitats including the substrate (organic debris, clay, silt, sand, gravel, and boulder) and macrophytes (floating or submerged) in the water. Each aquatic habitat was explored, either with the handnet or manually in order to collect the highest possible diversity of macroinvertebrates. After identification, the total number of individuals of each taxon was counted and stored in 70% ethanol. Data were subjected to ANOVA and multivariate analysis to discriminate between habitats, sites, and seasonality on their faunal attributes. Non metric multidimensional scaling (NMDS) segregated samples on the basis of seasons.

In total 48 taxa belonging to 27 families and 16 orders, representing Cnidaria, Nematomorha, Nemertea, Bryozoa, Annelida, Arthropoda and Mollusca were identified. Overall the most indicative groups in the sediments were mollusks, annelids and arthropods representing different ecological groups such as the detritivores, filter-feeders and sediment feeders, scrapers/grazers and herbivores. Higher abundance and species richness were recorded at site-III (Kahalgaon). The macrophyte vegetated marginal habitats recorded significantly higher species richness and abundance. The marine-originated families were also identified in the samples. The faunal composition and dominance pattern reveals the pristine and stable ecological conditions. The original composition of biological diversity persists in the middle reaches of the Ganga reflecting the suitability of the sampled riverine stretch for Gangetic Dolphin.

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Ichthyofaunal diversity, assemblage structure and seasonal dynamics in the freshwater tidal stretch of Hooghly estuary along the Gangetic delta

The tidal freshwater areas of estuaries have received little attention in ecological research, although they are often heavily stressed by environmental impacts. These critical habitats contribute significantly to the biodiversity of the entire estuarine system. The present study aims to describe the fish diversity, assemblage structure and seasonal dynamics through data collected by intensive sampling of the tidal freshwater stretch of the Hooghly estuary (June , 2010 to June, 2012), the largest estuary in India formed in the Gangetic delta.

The tidal freshwater zone of Hooghly has gained importance due to ecological changes during the post-Farakka period, as this zone covers 74% of the total estuarine stretch. During the study, a total of 155 fish species belonging to 49 families and 15 orders were recorded from this tidal freshwater zone. The exotic ornamental fish, *Barbonymus altus* (Tinfoil Barb), has been recorded in the tidal freshwater zone for the first time in Indian inland waters. A detailed analysis of the fish diversity revealed that of the 155 species recorded from the study, 29 species have been listed in the threatened fishes category by CAMP (1997). This includes 19 vulnerable (VU) species, 9 endangered (EN) species and one critically endangered (CR) species.

This signifies the role of the tidal freshwater zone as an essential fish habitat, due to its rich fish diversity, and as a sheltered area which favours the growth and survival of larval and juvenile fish assemblages.

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Socioeconomics of Fisherwomen of Hooghly Estuary- A Case Study

A large number of fishers depend on Hooghly Estuary for their livelihood. Women of fisherfolk communities played and continue to play a key role in the development of inland fisheries, but it remains unarticulated and unrecognized. In inland fishery sectors, women are thought of as “economically inactive” and merely play a supportive role as fishermen's wives. Women in the Hooghly Estuary community engage in a wide range of activities in fisheries and other related activities: as fish seed collectors; as workers (paid and unpaid) within the fisheries, in pre- and post-harvest activities; as workers in fish drying; as caregivers of the family and in maintaining social networks and the culture of the community; as workers in non-fisheries sectors to supplement the household income.

To assess the role of women in Hooghly Estuary, four important fish landing points were selected purposively. A semi-structured interview schedule was also used for data collection and 400 fisherwomen selected at random were interviewed personally. It was found that in the upper stretch of Hooghly Estuary, the participation of women in inland fisheries activities is less than that of the lower stretch. It was revealed from the study that 62 per cent of women overall had a medium level of participation (16.04-19.64) in various fisheries and income generating activities, while16 percent of women had a high level of participation. The rest (22%) had a low level of participation. Analysis of age structure of fisherwomen showed that those 27-49 years of age were mainly engaged in various fishery related activities (66%).

The total population study revealed 55.84% were male adults and 44.16% were female adults and that average family size was 6. Highest numbers of family members (38%) occurred among illiterate groups. Population composition of fisherwomen in Hooghly Estuary revealed that the majority belong to Schedule Cast (56%) and about 18 % were members of the Schedule Tribe population. About 15% of the population emigrated from Bangladesh. Most of the fisherwomen perceive (81%) that lack of credit facilities from the banks, is a major constraint they face. Moreover, in most of the cases fisherwomen were not aware of any type of facilities offered by the State or Central Government and in most cases, i.e. 77%, were not able to join various extension programs or training due to low literacy, poor exposure, and lack of timely information. Moreover, in most of the cases the training /extension programs were not gender sensitive, as reported by 83% of the fisherwomen.

Therefore, launching of a mass literacy campaign particularly for fisherwomen is highly needed.

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Environmental flows for sustenance of a river ecosystem – A case study with special reference to fish

Riverine ecosystems are among the most impacted ecosystems worldwide. Human activities, such as the construction of dikes, dams, groynes and weirs, the straightening and deepening of river channels, water transfer and pollution, have heavily modified most rivers. As a result, a large number of fish species became threatened or endangered and the fish productivity of most riverine ecosystems has declined. Hydropower is often considered as a clean and renewable energy source that is environmentally preferable to fossil fuels or nuclear power. However, hydropower transforms rivers and their ecosystems by fragmenting channels and altering river flows. Thus dispersal of riverine biodiversity and abundance, especially fish and fish food organisms and sediment dynamics, resulted in destruction of fish habitat.

The current need is to combine the protection of river ecosystems and the demands for social and economic development on which socio-economic benefits rely. Environmental flows that describe the quantity, quality and timing of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods in equilibrium when constructing new dams and re-licensing existing dams must be investigated. A study on environmental flows for a 780 MW hydropower project in Nyamjang Chhu River, Arunachal Pradesh, a 35-km stretch of the Nyamjang Chhu River flowing downstream from the barrage site to the Tail rest tunnel (TRT) was surveyed and four sites were selected for collecting samples for analysis of biological and physico-chemical parameters covering three seasons. Keeping *Schizothoraichthys* species as the target species, river flow estimation was examined through various methods such as Tennant method, Huges & Munster method and Building Block method. The Building Block method was found to be ideal for maintaining minimum depth and current for juvenile recruitment.

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Metal and pesticide pollution scenario of River Ganga

The River Ganga passes through a large number of cities, towns, villages and agricultural fields. A sizable fraction of effluents and sewages generated from all these diverse sectors enter into the river. The incoming water is therefore carrying huge amounts of organic substances, residues of the used pesticides and metals along with other contaminants. The pesticide residue studies on River Ganga and its tributaries indicated that HCH, DDT and endosulfan were the major contaminants in water and biotic community, while HCH, DDT, aldrin and dieldrin dominated the sediment phase. The residues in water frequently cross the permissible limits of US EPA for aquatic organisms and their consumers, indicating various risk levels. In the case of fishes, the permissible limits for HCH, endosulfan and DDT are exceeded only on some occasions, signifying minor risks for human consumption. Regarding metal contaminations, the uppermost stretch of the river Ganga, up to Haridwar, is relatively free from pollution. The middle stretch, receiving diverse kinds of effluents, is markedly polluted with different metals.

Although a significant stretch of the estuarine zone is densely industrialized and regularly receives effluents, the mixing and dilution with marine water is maintaining the metals in the lower level rather than in the middle stretch. However, in majority of the cases the reported levels were much higher than the US EPA permissible limits for aquatic organisms.

With respect to metal contaminations in sediments, the river is found to be moderately polluted. In fishes the contaminations of Pb, Hg and Cr are found to cross the limits on some occasions. The alkaline pH of water, high sediment transportation and rigorous flushing during monsoons are favourably protecting the river from accumulation of these toxic contaminants.

With respect to aquatic health, it is anticipated that the metal and pesticide contaminations might have adversely affected fish health and its population as a whole by down-regulating metabolic efficiency, growth, maturation, reproduction and recruitment, threatening species diversity and overall growth. Systematic studies are lacking in these aspects, however.

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Sustaining freshwater fish biodiversity and aquatic ecosystem in the tributaries of Ganges basin: Pattern, importance, biogeography and future challenges

India is one of the 17 mega biodiversity hotspots contributing to the world's biological resources. The vast fishery resources of this country are endowed with 14 major river systems which shares about 83% of the drainage. The Ganges basin contains a drainage area of about 1,060,000 km², which is the fifth largest in the world. Tributaries of the river basin serve as a key source of water for various services and, as a consequence, have almost certainly suffered changes in water quality and habitat.

Major environmental factors having negative impacts on fisheries are mainly human impacts on riverine morphology, disruption of ecology, intensive agriculture, and modern developments. Despite the urgent need for efficient conservation planning in the face of continuing changing freshwater environments, inadequate effort has been spent on applying systematic conservation planning. In this connection, important tributaries of the river basin were assessed and the spatial distributional patterns of fish assemblages in these tributaries were determined and important areas prioritized by using multiple biological indicators. The different conservation indices, i.e. Rarity and Origin, were assessed for various assemblage types to identify the areas with the most potential on which to focus the conservation efforts. The assessment also indicated that the tributaries of the Ganges basin are particularly relevant because they comprise several attributes associated with ecosystems susceptible to conservation: (a) high species richness with most diverse fish fauna which represents rich diversity of 116 native freshwater species. The information in this study highlights the fact that fish species living in these tributaries are significantly varied and sensitive to anthropogenic disturbance, since instances of local diversity depletion and shift in distribution pattern of fishes were observed. Although the tributaries have been impacted by various activities, intolerant species in all the sites of the fish communities have the potential to recover substantially if favourable conditions occur for long enough. To protect freshwater species and systems, there is an urgent need to counter the threats that jeopardize their survival.

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Invasion and impacts of alien fish species in the Ganga River system, India

Impact assessment of alien fish is one of the core elements for protecting fish biodiversity and food safety today. The benefits and risks of alien fish species in India have been assessed for ecological functions, within which they are embedded.

Impact assessment studies of some exotic fishes were carried-out for Yamuna and Ganga River systems. The studied impacts of exotic fishes revealed that *Oreochromis mossambicus* displaced carps from Ganga, and *Puntius dubiu*s and *Labeo kontius* from rivers of southern region. Bighead *Aristichthys nobilis* strongly competes with *Catla catla* and was found to have potential to hybridize with *Catla* and Silver Carp (Hypophthalmichthys molitrix). Common Carp *Cyprinus carpio* naturalized in rivers, and displaced local species like Mahseer *Tor putitora*, *Schizothorax* spp. etc. It also displaced an endemic fish species *Ostebrama belangiri* from Loktak Lake (Manipur). The Silver Carp formed a breeding population in Govind sagar Reservoir (Himachal Pradesh) and Kulgarhi reservoir (Madhya Pradesh) and changed the trophic structure thereby replacing *Catla* fishery.

The unregulated spread of *Pangasianodon hypophthalmus* in India has caused some concern particularly with regard to diseases. Recent upsurge in the population of *Cyprinus carpio* and *Oreochromis niloticus* besides occurrences of *Clarias gariepinus*, *Aristichthys nobilis*, *Pterygoplichthys disjunctivus* and others in the Ganga River has declined the catch of local fishes particularly Indian major carps and some others by 71.98%, whereas the catch of exotic fishes increased by 237.05%.

In this paper, the impact of some widespread exotic fish species in aquaculture is revealed to be a high risk rather than benefit. Aquaculturists and fish breeders have been suggested to follow the prescribed quarantine guidelines developed by this Institute for reducing the resultant economic losses to the country due to unplanned and indiscriminate introductions of alien fishes. The varying degrees of human intervention on alien species introductions without adopting biosecurity measures have been alarming. It was found that introduced species represented both a symptom and a cause of decline in river health and the integrity of native aquatic communities.

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Status, threats and conservation challenges to key aquatic fauna (crocodile and dolphin) in National Chambal Sanctuary, Madhya Pradesh, India

The Chambal River in India supports a rich fauna and flora including the endangered Ganges River dolphin and crocodile. The National Chambal Sanctuary comprises an intensively used riverscape and landscape with high levels of human poverty, inadequate law-enforcement and poor governance.

Threats to the continued functioning of the Chambal River as a living system have reached a critical level due to the exponential expansion of human populations. Population status of crocodiles and dolphins in a 425 km stretch of the Chambal River was determined by surveys conducted every year from 2007-2010. The average number of dolphins recorded during the surveys was 82.75±09.1, with an encounter rate of 0.19 indivduals km^{-1} (range 69-91), gharial 916.25±91.6 with an encounter rate of 2.15 indiv. km^{-1} (range 870-996) and mugger 235±27.7, with an encounter rate of 0.56 indiv. km^{-1} (range 194-301). Increasing demands for sand for development activities, and water abstraction for irrigation and energy generation coupled with mortality in fishing nets, are likely to affect dolphin and crocodile population. Recommendations for management and research are made to ensure the effective conservation of these species in the Chambal River.

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Development of Decision Support System (Dss) for environmentally degraded river system on the west coast of India through Bayesian Belief Networks (Bbn) based modelling

The west coast of India contributes about 3% of the total river basins of the country. A holistic approach towards Natural Resource Management (NRM) entails importantly consulting the stakeholders under an eminent participatory process. This study, spanning the period 2009 to 2012, has endeavoured to explore Bayesian Belief Networks (BBNs) based modelling to evaluate their efficacy as a Decision Support System (DSS) for Sabarmati River system, particularly its stretch under District Ahmedabad, Gujarat, India. This expanse received composite effluents discharge from industrial developments in and around Ahmedabad and the sewage from Ahmedabad city. Moreover, Sabarmati is also a water deficient basin due to anthropogenic invasions.

Hydro-biological attributes of the water of Sabarmati estuarine system were explored. The system recorded anoxic to low content of DO at certain sites which varied from nil to 6.92 mg l^{-1}. Prevalence of anoxic to hypoxic conditions indicated the system being highly environmentally degraded owing to receipt of brown/black coloured composite effluents. High free CO_2 up to 52.0 mg l^{-1} corroborated the above inference. Transparency regime (4.0 to 86.0 cm) exhibited zonal demarcation. Significantly high total alkalinity (88.0 to 743.0 mg l^{-1}) and specific conductance (242.0 to 4620.0 µ S cm^{-1}) were observed at expanse from Rasikpura to Anandpura, representing lower estuarine extent. Major nutrients viz. phosphate (0.019 to 0.259 mg l^{-1}), nitrate (0.629 to 2.810 mg l^{-1}) and silicate (13.431 to 23.749 mg l^{-1}) inferred moderate to high availability of these attributes. Total plankton abundance reflected wider fluctuation between 105 to 16996 nos. l^{-1} and phytoplankton (60.05 to 98.30%) was the main stay of this abundance. The zooplankton population (1.68 to 32.45%) also had significant contribution. The incidence of bacterium *Zoogloea ramigera* (0.12 to 1.04%), a bio-indicator of water contaminated with sewage and industrial wastes also indicated environmental perturbation. The most acclaimed bio-diversity indices as a function of benthic community structure discerned varying degree of environmental degradation. The Bayesian Belief Networks (BBNs) based model denoted the environmental degradation being true, up to 88.54% and demands immediate conception of a well-structured “River Health Restoration Programme”.

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Community empowerment for improved livelihood and ecosystem management

Community empowerment may help improve livelihood options and the ability to redirect and use external drivers for enhancing community well-being. The empowerment of local communities is increasingly important in a global society where people in one part of the world are dependent on ecosystem services in another part. This requires engaged communities with institutions that provide incentives to respond to and shape change for social–ecological sustainability. It also requires governance systems that allow for and support community processes that improve the capacity of ecosystems to generate services.

By focusing on the peoples' perspectives and their management systems, it becomes possible to address: how local users view ecosystem services and incorporate traditional knowledge and practices; how the community views indicators of human wellbeing; how local people manage ecosystem capacity behind those services, including management practices, institutions, and governance systems; how local people are affected by large-scale processes, and how they shape or cope with the resulting changes; and the linkages between communities, institutions (norms and rules), and organizations at other scales, and the role of social networks in the vulnerability or resilience of local people.

Hence, the overall perspective of this paper is that local communities are not just recipients of ecosystem services, but influence and shape the capacity of ecosystems to generate services. Despite claims of integrative analyses, social systems and ecosystems are often dealt with separately. An attempt is made to understand the feedbacks between community-level human adaptations and ecosystem change, and how communities cope with changes precipitated by processes or events operating at different temporal and spatial scales. The paper highlights the processes that characterize human–ecosystem interactions, also called social-ecological systems, in lower reaches of River Ganges.

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